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THE EVOLUTION OF SOIL SCIENCE AND ITS APPLICATION TO HUMAN PROGRESS

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THE EVOLUTION OF SOIL SCIENCE AND ITS APPLICATION TO HUMAN PROGRESS

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1. Human progress is slow and limited as long as people are required to use a high proportion of time to gather or produce enough food to keep themselves alive. The time required to produce enough food to meet the needs of a population depends primarily upon two factors: (1) the quality of the environment for growing food crops, and (2) the skill with which crop needs and environment are adjusted and synchronized. Progress is usually most rapid in areas where the natural environment is very favorable for food production or where it can easily be made very favorable. The early civilizations in the western world developed in the valleys of the Tigris and Euphrates Rivers in Mesopotamia, and in the Nile Valley of Egypt. Both of these areas are noted even today for their fertile soils, and in addition, have readily available from the rivers, ample supplies of water for meeting the demands of crops. Once these people had learned to spread this water over the soils, the success of their agriculture for a prolonged period was assured. Furthermore, these areas had temperatures favorable for growing good food crops and a relatively low humidity which was favorable for the growth of a great variety of crops but was not particularly conducive to the growth of many pests which restrict yields.

2. If the skills and technology of a people are not highly developed, an abundance of cheap food will be produced only in those environments which are very favorable for crop production under natural conditions. But as science and technology advance, the deficiencies of many environments can be diagnosed and corrected and food production can be expanded progressively into less and less favorable areas. Certain deficiencies are difficult to diagnose and are a barrier to agricultural development until science reaches a rather high level. Once the cause is determined, the remedy may be relatively simple and inexpensive to supply, but production is usually more expensive than on soils which are naturally very fertile. Because of this fact, the stronger and more aggressive elements in a population tend to acquire the best land and as the pressure of population increases and the people are forced to settle the less fertile land, it is usually the less skilled people who are forced out and compelled to farm the poorer soils.

3. Progress in such areas tends to lag because the soils with the most difficult management problems tend to get into the possession and fall under the management of the less qualified people. This pattern of land ownership exists in many less developed countries today. The better land is owned or controlled by people of greater means and better education, usually in rather large tracts. Fairly modern scientific management is used to produce crops, largely for export, as these crops generally return the highest profit per hectare. If land is abundant, this better land

may be farmed extensively or not at all and large tracts are often held intact awaiting higher and higher prices. These patterns of land ownership were established or at least initiated in most countries long before the development of soil science.

The Early Development of Soil Science

4. Thinking men, in all cultures and in all ages, have been intrigued with the causes of the differences in the productivity of soils. Many of Rome's most distinguished statesmen were also keen students of soil management. Although the basic sciences had not yet developed and they were consequently unable to find the reasons for many phenomena which they observed, nevertheless, as a result of systematic observation, they were able to develop certain practices which greatly improved the quality of their harvests. The use of manures, the influence of leguminous crops and the beneficial effects of limestone on certain soils were observed at an early date. The famous Norfolk rotation was developed in England and widely applied before our knowledge of chemistry was adequate to explain the reasons. This development alone, is accredited with doubling the yields of wheat in Britain.

5. The art of soil management, then, had made considerable progress by empirical techniques long before soil science developed. This was due largely to the fact that soil science is, in many of its aspects, an applied science of great complexity. In order to obtain an understanding of its mysteries, tools of research developed by chemists, physicists and microbiologists, et al, had to be perfected for simpler systems before they could be applied to the complex systems in soils. Soon after Berzelius, Liebig and other chemical pioneers developed methods for the chemical analysis of plants and rocks, these tools were applied to soils, manures and crops grown on soils with different manurial treatments. This approach supplied data which eventually gave an insight into the reasons for the effectiveness of management practices which had long been used by the better farmers.

6. Soils had many properties which attracted the attention of the early students of physics. They differed widely in their capacity to swell, shrink and crack, in the ability to transmit, absorb and retain moisture; in their tendency to granulate under certain conditions and to disperse under others. They responded very differently to the action of frost. Many diverse environmental factors were found to influence the temperature of soils and these temperature differences had in turn an effect upon the early growth of crops, especially in temperate regions. Physicists observed quite early that the relationships between water and soils were quite complicated. Some of the water moves through soils with but little resistance under the influence of gravity, while part of it is retained with forces so great that plant roots are unable to extract it. These problems have been studied for over a hundred years but scores of soil physicists continue to find facets of the problem fascinating and not yet satisfactorily explained.

7. When the microbiologist examined the soil with his newly discovered techniques, he found that it was inhabited by a very complex flora and fauna, with millions of microorganisms actively engaged in tearing down the plant and animal residues which happen to fall upon the soil and converting them into a material called humus, a product characteristic of soils. Later, about 1870, they discovered in the nodules of the roots of certain legumes, bacteria which had the unique capacity of absorbing elemental nitrogen from the atmosphere and building it into the proteins

necessary for their life processes. At last the reason for the beneficial effects of legumes upon succeeding crops, observed centuries earlier by Roman farmers, was partially explained. This subject has been energetically pursued since that time, but all facets of this very basic problem have not yet been fully clarified.

8. Geologists were interested in rocks and in the processes by which they disintegrated or weathered and were finally transformed into soils. In the case of young soils, the characteristics of the soil were plainly influenced by the nature of the rocks from which they were formed. The earliest efforts to classify soils were based upon the nature of the rocks from which they originated. As studies were expanded into areas in which the soils were much older geologically, the influence of the parent rock became less obvious and in many cases disappeared altogether. This necessitated a restudy of the problem of the classification of soils and led Dokushaiev and his students to develop a genetic system of classification, based primarily upon the properties of the soil profile itself. This was a great step forward. But, as it was applied to soils in different areas, it too, was discovered to have weaknesses and efforts are now underway throughout the world to develop more satisfactory systems of soil classification. Soil scientists are approaching the problem with more caution than in early years and the latest effort in this direction is referred to as the "7th approximation", indicating that the best we have today is recognized as being imperfect and merely one more stage toward our ultimate goal. Nevertheless, a great deal is known about the soils in various parts of the world. We know what the major types of soil are and we know in a general way where they are located and something of their agricultural potential. An international cooperative effort is underway to produce a soil map of the world. It will not be perfect when completed, but it will represent an additional coordinated effort to supply a picture of the soil resources available to us.

9. A soil survey can be of great value to the leaders of a developing country. If they are to plan wisely, they need to know what soils they have, where they are located and what use they can best serve. They will need to establish priorities for the development of different sections of the country. Cities will have to be located, highways will have to be planned, agricultural research and educational centers will have to be established in the most favorable locations. It is important that these research stations be well located so that the findings made there will be applicable to large areas having similar soils in other sections of the country.

10. Botanists, plant physiologists and ecologists can also make important contributions at this stage. A study of the natural plant cover should accompany and supplement the soil survey as it will often provide clues of value for determining the agricultural potential of a new region. Knowledge of plant physiology is indispensable to the student of soil fertility. Thus, we see that all of these sciences contribute to soil science and to our understanding of the soil as a medium for the growth of crops.

The Soil as a Medium for the Growth of Crops

11. The soil is a living, dynamic system which undergoes many cycles of changes which need to be understood when planning management practices, for it affects the growth of crops in many ways:

(a) It must be a medium suitable for the germination of seeds and

favorable for the development of a healthy root system.

(b) It must have a chain of pores open to the atmosphere and capable of conducting enough oxygen to the roots to meet their respiration needs.

(c) It is the source of water for the plant and must have a capacity for storing water for the use of the crop during the periods between rains. This is extremely important in areas where the rainfall is inadequate or poorly distributed.

(d) It is the source of all the nutrients essential for the growth of the crop. The macronutrients; calcium, magnesium, potassium, nitrogen, phosphorus and sulphur are needed by practically all plants in relatively large amounts. In addition, all plants require small amounts of manganese, copper, zinc, boron, molybdenum and iron. Only minute traces of the latter group are needed in the enzyme systems of the plant, but their absence may result in crop failure. These requirements are specific and one element can substitute for any other to only a very limited extent.

12. It is especially important that adequate amounts of nutrients be present at the time the crop is being established. It will help to get the crop off to a good start. Most crops grow much more rapidly at one period than at another. It is important that the supply of nutrients be adjusted to and synchronized with the needs of the crop at each stage of development. The supplies of all of these nutrients need to be properly balanced. It has been known since the time of Liebig that the amount of growth of a plant is limited by the supply of the nutrient present in smallest amount in proportion to the requirements of the crop. This "law of the minimum", refined in many ways in the last century, is still one of the cornerstones of soil management. The problem of maintaining an adequate supply of nutrients in soils in a form in which they can be absorbed by plants is complicated by the fact that readily soluble nutrients are washed out of the rooting zone during periods of heavy rains. Some of the nutrients supplied react with the soil and in many cases form compounds which are so insoluble that their effectiveness is greatly reduced. There are all grades of interactions between these extremes which the intelligent farmer must understand and appreciate in devising efficient systems of soil management.

The Present Status of Soil Science

13. Soil science has reached a fairly high state of development in the technically more advanced countries. The larger of these countries can number their soil scientists in the thousands, the smaller countries in the hundreds. Most of them have good institutions for the advanced training of soil scientists and the quality of this training is steadily improving. The proportion of soil scientists trained to the Ph.D. level is increasing each year and in many countries job opportunities are limited for those who are not trained to this level.

14. Research in soil science in these countries has greatly expanded in the last two decades. The volume of literature emanating from their laboratories has greatly increased. Each of the major countries has its own professional society of soil scientists with large memberships which bring their members together at intervals for the reading of papers and

the exchange of ideas. The International Soil Science Society has been in existence for almost half a century and has about 4,000 members in 74 countries. Meeting at intervals of from 3 to 5 years, it brings the soil scientists of the world together for technical discussions and personal contacts. The volume of technical literature in soil science is so large that no one can hope to keep up with all of it. This has resulted in the preparation of many specialized monographs which review in a critical way, the literature dealing with specific areas.

15. In order to bring new developments to the attention of interested farmers, extension workers are trained in soil science and their training is kept up to date by frequent conferences with research workers. In the advanced countries, important discoveries in soil management are brought to the attention of farmers and put to use by them with a minimum of delay. In many cases, the more alert farmer is applying new research information on his farm before it is published in a technical journal. Governments are supporting research more liberally than in the past, because they have found that it is one of the best investments that they can make. It is difficult to evaluate the contributions which agricultural research has made to the development of the more advanced countries, especially in the last quarter of a century, but they have been very substantial.

16. In the United States for example, less than 9 percent of the population is now living on farms. This small fraction of the population is producing all of the food needed by the entire population with surpluses for export trade and for meeting emergencies throughout the world. The cost of food to the consumer has been lowered when expressed as percent of income. The wage earner is now spending only about 20 percent of his wages for enough food of high quality to support himself and family. Over 90 percent of the population has been freed from work on farms to perform other services demanded by our rapidly growing economy and for cultural pursuits. All of this is being done with less land under cultivation than 25 years ago, and there is every evidence that the productive capacity of the land now farmed is being maintained. While the yields of many crops have more than doubled in the last quarter of a century, there is abundant evidence that we have not yet reached our peak. As a matter of fact, there is rather convincing evidence that the present yields of crops can be doubled with but little, if any, increase in unit costs of production.

17. The status of soil science in the less developed countries is, in many cases, lamentable. They have but few, if any, trained soil scientists, but few laboratories and these are often poorly equipped. Their libraries are small, the books and journals often poorly selected and out of date, and therefore, often little used. Many institutions in which agricultural workers are being trained suffer from the same deficiencies. In many of the former colonial countries, the situation has frequently deteriorated since independence. Most of the better trained scientists were expatriates and many of them have left without leaving qualified replacements. Most of the great tropical research centers have been closed down and in many cases it will be years before they can resume a research program comparable in scope and quality with that underway a decade ago.

18. The situation is aggravated by the fact that agriculture is often held in low esteem by the young people now receiving an education in these countries. They are anxious to get jobs in the city and are more interested in glamourous subjects like atomic physics and space exploration than in

soil science. International trade is bringing many new, attractive products and conveniences to their markets. They naturally want to industrialize and make these products in their own countries. Unfortunately, they do not see or fully appreciate the significance of the efficient agriculture which has made such industrial developments possible in the countries with a more mature economy. Changing such attitudes and building up a corps of able teachers, research workers, and other leaders for agriculture, is one of the most important problems confronting many of the developing countries.

Applying Soil Science for Human Progress

19. Soil science, as we have seen, is basic to improved agriculture but it is not a simple matter which can be applied overnight. If we are to benefit from its full potential, it must be the central core around which an integrated system of management is developed. This system of management, to be efficient, must include the best combination of practices which plant breeders, agronomists, plant pathologists, entomologists, plant physiologists, agricultural engineers and other specialists can devise. As pointed out above, many of the advanced countries are now reaping an abundant harvest from the investment made in agricultural education and research over the last hundred years. There is every reason for thinking that the potential for development is equally great in the agriculturally underdeveloped countries.

20. A high proportion of these countries lie in the tropics. They have problems that are different and in some cases more difficult than corresponding problems in the temperate region; but they also have the very great advantage of having a growing season 12 months long which permits the growth of crops throughout the year. It has been estimated that there are over 200 million people supporting themselves by some form of "shifting agriculture" or "natural fallow" in the tropical areas. They are exploiting over 3.5 billion hectares of land for it requires, under this system of management, about 15 hectares to support one person. This is a very remarkable system of agriculture developed many centuries before the principles of modern science were discovered or the products of modern industry were available.

21. It developed in slightly modified forms in the tropical sections of all the continents and is widespread in Africa, Asia and Latin America. It consists of clearing land from jungle, burning the cover, planting to crops for from three to five years; then, as yields decline and weeds increase, the land is abandoned, the jungle takes over for from 15 to 20 years and then the cycle is repeated. From 85 to 90 percent of the people must engage in farming to produce enough food to support themselves with this system. Under such circumstances, these people can contribute but little to human progress except how to subsist in a hostile environment. It works satisfactorily until population pressure forces a lengthening of the cropping period and a shortening of the fallow period. When this occurs, the beneficial effects of the fallow decrease, crop yields decline, and the people are forced to reduce their numbers or to migrate.

22. Taiwan is a good example of what can be done by an industrious, literate people with good technical leadership, by the application of science to a situation requiring very intensive management in a tropical environment. This tiny island, three fourths of which is mountainous, has developed an agriculture which supplies its population of about 10 million people with a diet far above the average in Asia, and a surplus of sugar, bananas, pineapple, pork and other products for export to

neighboring countries. This has been done by the skilled use of fertilizers, good seed and cultural practices combined to give yields of crops which compare with the best obtained anywhere. In addition, they have developed an ingenious system of multiple cropping which gives from 2 to 5 crops per year. As a result of such combinations of farming practices, the farmers of Taiwan often produce from 10 to 30 times as much food per hectare as is produced under the shifting agriculture system.

Summary

23. Human progress is slow as long as people must devote a high proportion of their time to producing enough food to feed themselves. The amount of time required depends upon the qualities of the environment and the skill with which it is managed. The labor required for food production is usually high when crop yields are low. Crop yields are higher when the natural environment is favorable or when it can be made favorable by skilled management. An understanding of the principles of soil and crop science is essential to the development of the sound management practices necessary to obtain higher yields.

24. Soil scientists are confident that the world has the soil and water resources necessary to produce an adequate diet for all the peoples of the world for at least a couple of generations, if they are properly developed and managed. The experience of Mexico, Taiwan and many other countries indicates that it is now possible to expand food production at rates from 5 to 8 percent per year. This is about twice the rate at which populations normally increase. Most of the broad scientific knowledge necessary is already available. The additional information needed on local environment can be obtained within a decade or less. There are, however, other requirements which must be met if we are to put this knowledge to work.

25. The efficient development and use of these resources will require: (a) increased sources of power and the machines necessary to use it, (b) increased supplies of fertilizers and lime, (c) increased supplies of chemicals for pest control, (d) better seeds, with greater genetic potential for utilizing the improved environment, (e) better water control; drainage to remove harmful surpluses and irrigation to supplement deficiencies in rainfall.

26. The amount of capital required for these developments is large. Fortunately, most of these expenditures, if wisely made, can be self liquidating. The more highly developed countries have found that such investments are very profitable. They should be autocatalytic in their effect on the economy of the country. If wisely handled, it will cost much less to make the necessary investments than to fail to make them. The advanced countries have made them and are now reaping the benefits, the less developed countries have not and are suffering as a result.

27. Progress in a country is more frequently limited by the attitudes, motivation and capabilities of its people than by all other factors. In many of the less developed countries people of wealth and in positions of great power are preoccupied with maintaining status quo. Usually this attitude is shortsighted in that it fails to recognize new outlets for their talents and resources and tends to inhibit their overall economic and social progress so important to all elements of the population.

28. In this scientific age, the development of a country is more likely

to be limited by its supply of educated people than by any other factor. An investment in the education of its people is one of the most profitable that a country can make. Unless it is made, the returns from all other investments will be jeopardized or at least reduced. Modern agriculture and industry cannot be directed and operated efficiently by uneducated men. The proportion of highly trained men required is steadily increasing. To produce the numbers of educated men needed, teachers, schools and universities, and time are needed. Until local personnel can be educated to the required level, and in sufficient numbers, leadership from other countries should be recruited. Men with experience in the agriculture of the country or region should, in general, be preferred. Well trained, experienced, sympathetic expatriates, if properly supported, may be among a newly independent country's most valuable assets during the difficult period in which school systems are being expanded, universities and agricultural research facilities developed and other essential services and goods provided.

29. The experiences of several countries in the tropics and that of a few exceptionally skilled farmers in most other countries, seem to justify our faith that farmers in practically all countries can produce enough food and other agricultural products to meet the basic needs of their people. If they are to do so, however, the soil and other resources of the country must be wisely developed and managed. Efforts to ensure this should receive top priority in all countries.

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